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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Aviation Fuels

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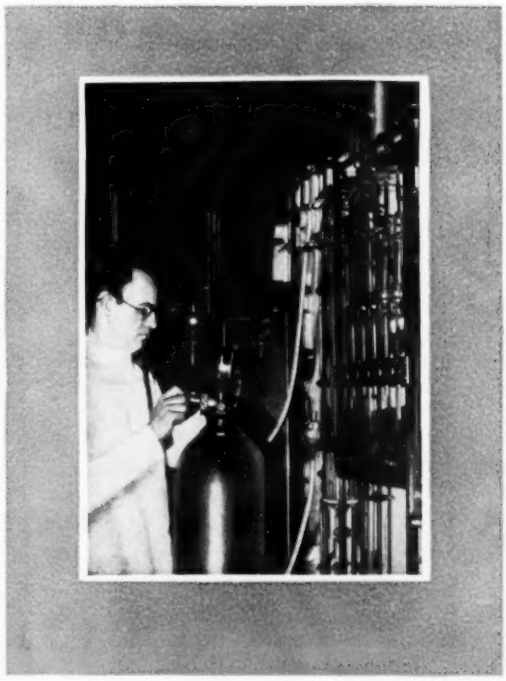
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

Aviation Fuels



HYDROGENATION EQUIPMENT developed at the Beacon, New York, Research Laboratories of The Texas Company for the exact analysis of the unsaturated components of petroleum gases. ● This apparatus is used as one of the primary controls for production of high anti-knock aviation fuels by the alkylation process.

OVER the past decade more new processes have been developed for gasoline manufacture than in any other similar period in the history of the petroleum industry. These developments were particularly directed towards raising anti-knock value or octane number and increasing the available gasoline supply at a price which the consumer could afford.

The tremendous increases in octane number of aviation gasoline have written an entirely new chapter in airplane engine development. Previously, each attempt by the engine designer to increase specific power output or B.M.E.P. was thwarted by knocking, detonation, and engine overheating.

The text of this issue will illustrate briefly why anti-knock properties are so important, how high octane number fuels lead to increase in engine horsepower, increase in maximum and cruising speeds, increase in payload, and reduction in fuel consumption. In either the commercial or military airplane, these factors are vitally important, since every pound saved in power plant and fuel weight means an additional pound available for payload.

Some of the outstanding processes used to make aviation gasoline are discussed briefly and illustrated by abridged flow charts.

To enable a better understanding of the various properties of aviation gasoline, the more important laboratory test methods are also discussed with the significance of each test. Finally, "Safety Fuels" and Diesel Fuels are mentioned and their properties outlined.

TEXACO
REG. T.M.

LUBRICATION

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Aviation Fuels

IN tracing aircraft engine development back over a ten year period one is amazed at the tremendous increases in performance. A typical example of performance increase is found in the development of the Cyclone engine over a period from 1929 to 1939 (Fig. 2). This data is even more impressive when one realizes that the bore and stroke and number of cylinders of this engine has not changed in the meantime. Over this period the maximum horsepower for this engine increased from 550 to 1200. The horsepower per cubic inch of displacement has increased from 0.30 to 0.66. This large increase was made possible by raising both B.M.E.P. and engine speed. Other manufacturers likewise have made similar increases in power.

Two other important engine changes occurred during the past decade, namely, lower specific weight and reduced specific fuel consumption.

Courtesy of Pan American Airways

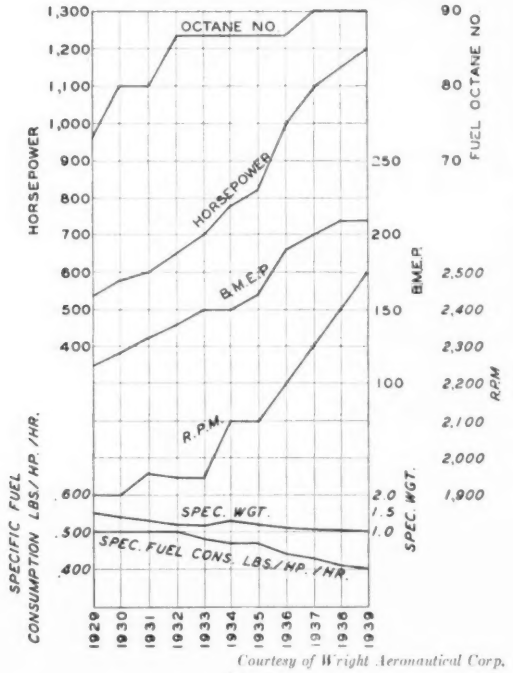
Fig. 1—Pan American Airways Transatlantic Clipper during takeoff (Boeing model 314). These planes use 95 ASTM octane no. fuel.

Methods of Boosting Power and Reducing Fuel Consumption

The aircraft engine, like other internal combustion engines, is a heat engine which converts heat energy into mechanical power. The combustion of fuel and air within the cylinder supplies the heat energy to operate these inter-

nal combustion engines. Only part of this heat energy is converted into power while a larger portion, for various reasons, is lost through the exhaust and cooling systems. A smaller amount is also expended in overcoming friction and pumping losses within the engine.

CURVES SHOWING RESULTS OF DEVELOPMENT ON THE CYCLONE ENGINE OVER A PERIOD OF TEN YEARS



Courtesy of Wright Aeronautical Corp.

Fig. 2

The most effective method of boosting power is to supercharge. This method packs more fuel and air into the cylinder from which is derived an increase in power. As one might expect there are many practical limitations which control the extent of boosting power, such as cooling capacity of cylinders, structural restrictions of the engine, etc. But the greatest limitation is detonation which depends chiefly upon the octane number* of the fuel. For this reason the increased availability of fuels with higher and higher octane ratings has allowed the engine company another opportunity to boost power.

Raising engine speeds has been employed also in boosting power, particularly for takeoff conditions. In this connection propeller manufacturers should be given credit for the development of the adjustable pitch feature.

Increasing compression ratio has also contributed to recent increases in power output. Boosting power by this method is less effective than either supercharging or higher speeds. Its chief advantage, however, lies in the fact that higher compression ratios create higher thermal efficiencies and lower fuel consumption. With a high compression ratio more of the heat energy is converted into useful work than with a low compression ratio. Therefore, less fuel is required to produce a given horsepower with high compression ratios.

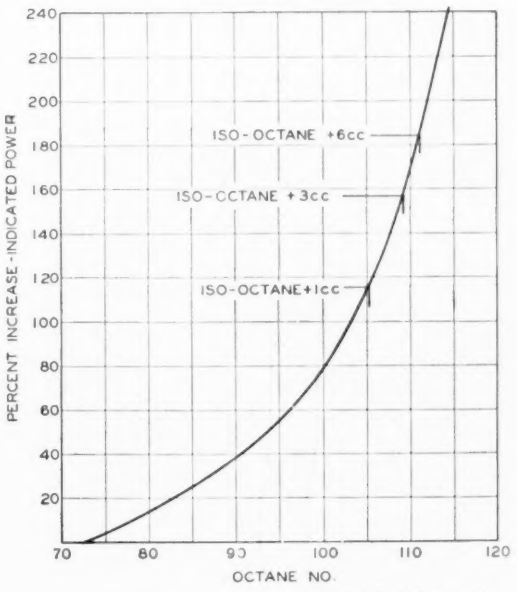
Where the airplane is to operate over long distances such as in transoceanic service, the fuel consumption as an item in the disposable load must be reduced as much as possible. For this reason the engines used in transoceanic planes usually have higher compression ratios than those installed in land planes.

Results in Airplane Performance

In an airplane, as every airline operator knows, every pound saved in weight is an extra pound available for payload. Over the past decade the specific weight and fuel consumption of many engines have decreased. Weight reductions of these two items has allowed the airplane designer to make substantial increases in payload or passenger capacity.

But what about aviation fuel development?

INDICATED POWER INCREASE VS. OCTANE NUMBER



Courtesy of Ethyl Gasoline Corp.

Fig. 3—Curve showing the increase in indicated horsepower obtainable with higher octane fuels compared with 73 octane number grade.

Prior to 1929 aircraft engine designers found it difficult to raise B.M.E.P. because of detonation troubles. Up until this time there was no standardized means of measuring the knocking tendencies of fuel. Consequently, the power

* For definition of octane number refer to discussion on page 101.

output had to be restricted to enable satisfactory operation on any fuel which the operator might use. The establishment of the octane scale, therefore, provided the engine designer with one of the most useful yardsticks which he could use in subsequent development work.

Following the introduction of the octane scale, there was a period of intensive development in the production of high octane fuels. Fig. 3 shows the relationship of permissible power output (as limited by detonation) to octane number in a supercharged laboratory engine. This curve shows that indicated power increases rapidly with octane number and especially so above 90 octane number. In other words, the increase in power per unit increase in octane number climbs at a faster rate above 90 octane. At a point corresponding to 128 octane number (on the extrapolated scale) the possible increase in power is theoretically unlimited.

Another example of increased power available with higher octane number fuels is found in the Pratt & Whitney Twin Wasp Engine. On 95 octane number (A.S.T.M.*) fuel this engine is capable of developing 22% more power than with 87 octane number (A.S.T.M.) fuel. Except for supercharging all factors such as speed,

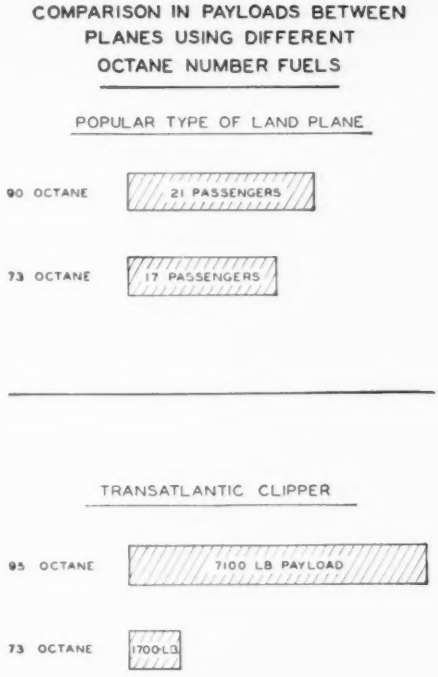
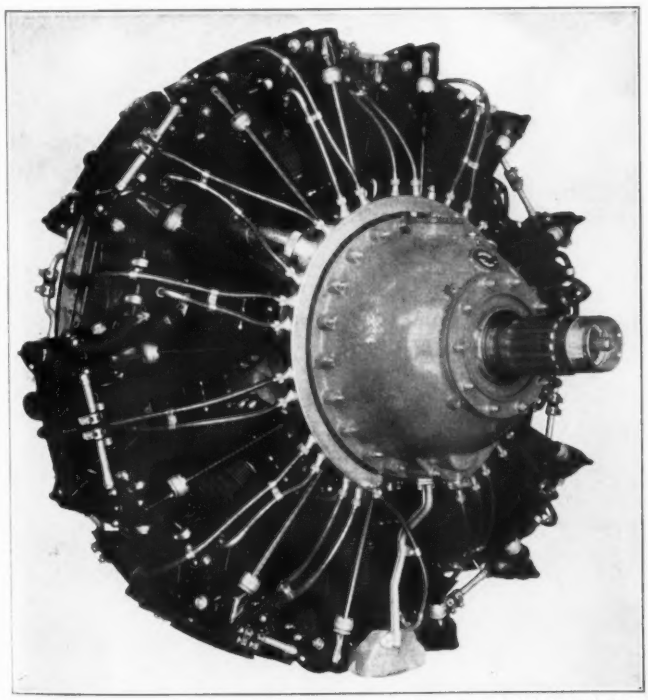


Fig. 5—Estimated differences in payload between two land planes and two transatlantic seaplanes using fuels of different octane ratings. It was assumed that the engines had similar takeoff horsepower and were designed for the fuel used.

* ASTM—American Society for Testing Material Method. Formerly referred to as CFR Motor Method.



Courtesy of United Aircraft Corp.

Fig. 4—Pratt and Whitney Twin Wasp Aircraft engine, used in transport planes. These engines are designed for either 87, 90 or 95 ASTM octane no. fuel. Takeoff horsepower varies from 1065 to 1215 depending upon fuel used.

compression ratio, etc., are identical in each case.

It is sometimes difficult to appreciate how these increases in engine performance have affected the airplane. Each time that power is boosted on current engine models, the airplane designer enlarges his plane or increases the payload accordingly. Another reason why comparisons are difficult between other types of airplanes using 73 octane fuels and those designed for 90 octane fuel is the fact that there have been numerous advances made in the design of the airplane itself. Cantilever wing construction, better engine location, higher wing loading and retractible landing gear are only a few examples of the achievements contributed by the airplane designer.

In Fig. 5 a purely hypothetical example is illustrated showing differences in payloads between two types of transport planes designed for different octane number fuels. Takeoff, horsepower, cruising speed, total drag, gross weight and flight

time were assumed to be equal. Note the appreciable sacrifices in payload of passengers which would occur if these airplanes had to be equipped with engines designed for 73 octane fuel.

TYPES OF FUELS AND METHODS OF REFINING

Gasoline consists of two basic chemical elements, namely, hydrogen and carbon. These two elements in combination produce compounds called hydrocarbons. The number of different hydrocarbon compounds possible are almost unlimited. In aviation gasoline alone, the number of different hydrocarbons run into the thousands. The molecular structure of the different groups of hydrocarbons are too lengthy to be covered in this discussion.

Of the one and one quarter billion barrels of crude oil produced in this country last year, only a very small percentage was suitable for straight run aviation gasoline. The octane rating of the average straight run gasoline is somewhat under 60. However, by careful selection of crude source a straight run aviation gasoline can be made with an octane number of 70 or slightly higher but the quantity is definitely limited.

Straight Run Method

Most of the aviation gasoline consumed in commercial service today is made by distilling a fraction from the crude with a boiling point range between 100 and 300 degrees Fahr. This is called the straight run method (Fig. 6). The aviation gasoline fraction is separated from the normally gaseous hydrocarbons and the less volatile components used for kerosine, gas oil or Diesel fuel, fuel oil, etc. Depending upon the crude, this gasoline may or may not require additional treatment to improve its color, gum and odor stability.

The higher octane grades (commercial) 80, 87 and 90 ASTM are made by the addition of tetraethyl lead (referred to as lead) to the straight run product. At present the lead addition for the 90 ASTM octane grade is held to a maximum of 4 ml.* per gallon.

For higher octane grades, the octane rating of the base gasoline is usually increased by blending with iso-octane or other synthetic fuels having higher anti-knock rating. Iso-octane was virtually the first high octane blending agent to be used commercially in aviation gasoline.

Polymerization and Hydrogenation

This valuable hydrocarbon was originally made in commercial quantities by the selective polymerization and hydrogenation processes. (Fig. 7.) This process uses selected refinery gases discharged from the cracking units. These gases are available in large quantities and were formerly used for refinery fuel or wasted. Under the proper conditions these gaseous hydrocarbons are combined with one another to form heavier or less volatile hydrocarbons with boiling points suitable for use in gasoline having very high anti-knock ratings. Polymerization is the term applied to this reaction of making heavier hydrocarbons from lighter hydrocarbons. However, to improve the stability of this synthetic fuel, hydrogen is combined with the selected polymer gasoline to produce iso-octane which has good stability and a knock rating of 100 by definition.

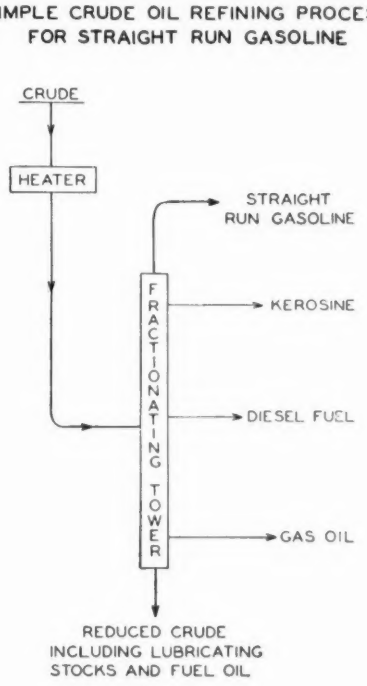


Fig. 6

Alkylation

During the past year alkylation has attracted the greatest attention as a process of making high octane aviation fuels. Alkylation like polymerization utilizes normally gaseous hydrocarbons to form a variety of liquid hydrocarbons. (Fig. 8.) It employs slightly different types of hydrocarbons, however, and produces a range of liquid hydrocarbons which have the desired volatility for use in gasoline.

The production of iso-octane formerly required two separate steps, namely, selective polymerization and hydrogenation, whereas in alkylation only one operation is required. The raw materials employed in this process are

* Milliliters.

available in large quantities which will assure a large future supply of alkylate fuel for blending purposes. This fuel is already noted for its very high knock rating (averaging 90 or higher),

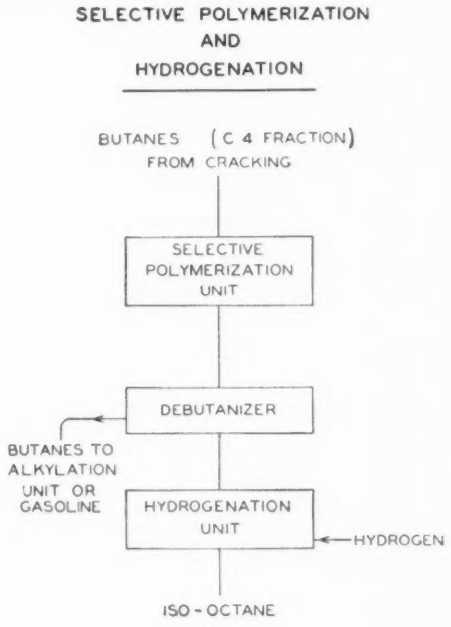


Fig. 7

good stability, and excellent response to octane number increase by the addition of lead.

Alkylation is also a valuable source of high octane safety fuel. This type of fuel will be discussed later under safety or high flash fuels.

Alkylation is by no means the only promising method of making high octane fuels. More recently catalytic cracking appears to have good possibilities in this connection.

Catalytic Cracking

The special processes already mentioned dealt with the building up of lighter hydrocarbons into heavier hydrocarbons having a range of boiling points suitable for use in gasoline. Cracking processes produce the reverse or split apart heavier less volatile hydrocarbons such as gas oil, into lighter fractions usable in gasoline. (Fig. 9.)

For many years petroleum chemists have been conducting research work on the production of high octane fuels by cracking in the presence of catalysts. The latter is any substance that affects the rate of a chemical reaction without taking part in that reaction. Quite recently, however, catalytic cracking has been developed commercially. Heretofore most of the cracking methods have been of the thermal type depending upon temperature and pressure to break apart or "crack" the heavy hydrocarbons. In referring to cracking methods it is important to specify whether it is the thermal or catalytic method.

The charging stock used in this catalytic cracking process is gas oil (similar to Diesel fuel). The latter is heated and the vapors pass through the catalytic chamber where it cracks into lighter or more volatile hydrocarbons. This cracked stock is next fractionated, or the portions with the proper volatility are separated from the overall cracked stock, treated to improve its storage stability and afterwards used for blending.

Catalytically cracked gasoline has not been used to any great extent in aviation gasoline due to stability limitations in current specifications. It is expected that some compromise may be reached where specifications are modified to allow some of this fuel for certain classes of service.

METHODS OF TEST

Octane Number—What Is It?

Octane number is an expression used to indicate the anti-knock quality of a given fuel. Its units are based upon the knocking tendencies of two pure hydrocarbons, normal heptane,

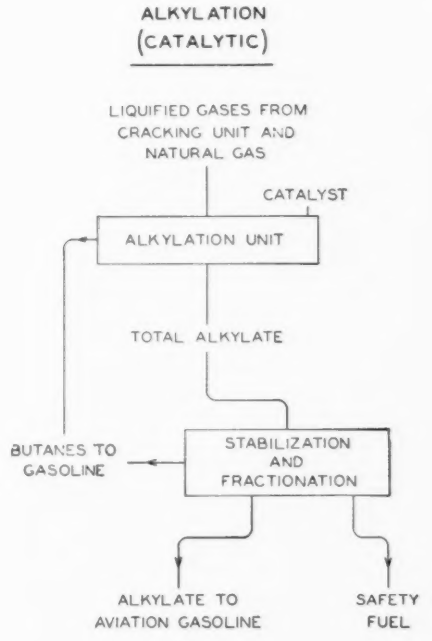


Fig. 8

and iso-octane, in a standard test engine under specified conditions. Normal heptane is notorious for its bad knocking tendencies, and is given a value of zero. Iso-octane is noted for its exceptionally good resistance to knocking

and is given a value of 100. Numerically, the octane number of any fuel is the percentage

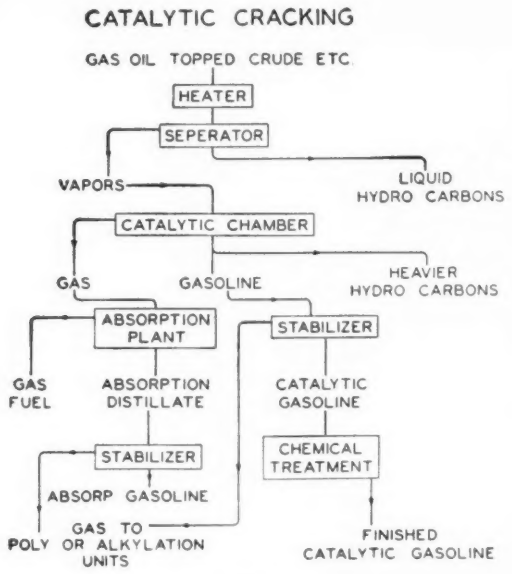


Fig. 9

by volume of iso-octane in normal heptane that matches the knocking tendencies of that fuel.*

Octane number is determined in a single cylinder test engine especially designed for this purpose. (Fig. 10) The fuel to be tested is supplied to the engine, and compression ratio is increased until knocking develops. The knock intensity is measured with a bouncing pin or thermal plug and recorded on the knockmeter. A mixture of reference fuels is next supplied to the engine. The proportion of reference fuels are varied while running the engine until mixtures are found which give slightly less and slightly greater knocking than the fuel being tested. This procedure is called "bracketing" the unknown fuel. In each case the knockmeter values are noted. The exact octane number can be taken from a plot showing octane number versus knockmeter values.

The commercial development of higher octane fuels has been so rapid within the past few years that the present octane number scale is already inadequate. Therefore, the industry was faced with the necessity of choosing a different scale for values in excess of 100 octane. Some proposed an arbitrary extrapolation of the present knockmeter curves, others suggested a new reference fuel with greater anti-knock value such as triptane in place of iso-octane. Early proponents of the highest useful compression ratio (H.U.C.R.) again suggested the possibilities of this scale. At the present time the petroleum industry and engine companies jointly favor the use of iso-octane plus lead. For example, ratings above 100 octane will be expressed as 100 octane (iso-octane) plus — c.c. or ml. of lead.

Anti-Knock Test Engine Conditions

In the United States two standardized sets of engine conditions are used today in rating octane numbers of aviation gasolines. It is expected that these two methods will be replaced by a new method during the coming year.

Fig. 10—C. F. R. Laboratory test engine used to determine octane number.

	ASTM Motor	Army
Bore and stroke, inches	3¼ x 4½	2¾ x 4½
Engine speed, r.p.m.	900	1200
Jacket temperature, degrees Fahr.	212	330
Mixture temperature, degrees Fahr.	300	No heat
Spark advance, degrees BTC	26*	30
Measurement of knock intensity	Bouncing pin	Thermal plug

*Varies with compression ratio.

* Iso-octane should not be confused with normal octane as the latter has a lower knock rating than normal heptane. Due to the high cost of chemically pure iso-octane and normal heptane, less expensive secondary reference fuels are used for routine testing. The latter fuels are matched against the primary standard iso-octane and normal heptane.

In addition to the above methods, several others are currently used for rating automobile fuels. Both ASTM Motor and Army methods give almost identical ratings to conventional unleaded straight run gasoline. For leaded straight run fuels, the two ratings diverge above 80 octane to as much as 3 to 5 octane units with 2½ to 3 cc. of lead. In other words, a fuel with an ASTM Motor rating of 87-89 will usually show 92 Army octane. Also, a fuel with 97-98 ASTM Motor Method may show 100 octane by Army Method.

The reason for the different methods of octane test is that no exact correlation has been established between full scale engine and laboratory test engines. The ASTM Motor Method is used to rate fuels in commercial service, while the Army method is used to rate military fuels. Therefore, when reference is made to octane number it is necessary to state the method of test.

Volatility—Method of Test

The ASTM distillation test is the standard method used by the American petroleum industry to measure gasoline volatility (Fig. 11). One hundred ml. of gasoline are placed in a flask, and heat applied at a definite rate. When the first drop falls from the condenser into the graduate, the temperature of the vapor in the flask is noted. This is called the initial boiling point (I.B.P.). When 10, 20, 30% etc. of the fuel has been recovered the corresponding temperature is recorded. The end point is the maximum temperature observed on the distillation thermometer and is usually reached after the bottom of the flask has become dry. This data can be plotted on a graph for comparison with other fuels. (Fig. 12.)

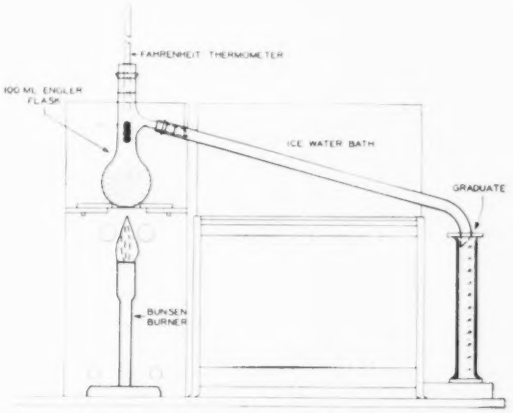
Significance of Volatility

This test is very valuable and is used to control factors that influence starting, vapor-locking, distribution acceleration, economy, and in the case of motor gasolines—dilution. Its significance with respect to vaporization of fuel in the engine intake system, however, is only relative. Since the pressure, temperature and rate of air circulation in the inlet system are somewhat different from the conditions of this test, the distillation data cannot be applied directly to the engine. Another example of this difference can be noticed by the rapidity with which aviation gasoline evaporates at room temperature when spilled, even though the 90 per cent point is 230 degrees Fahr.

The significance of the different points in this distillation test which are universally accepted may be summarized as follows:—

I.B.P. (Initial Boiling Point)—has virtually no importance.

10% Point—This point is often used to judge the ease of starting and vapor locking. Those fuels having the lowest 10 per cent temperature will afford easiest starting, especially during cold weather. In order to start an airplane engine, it is necessary to produce the proper fuel-air mixture in the manifold or inlet system. Under cold conditions, only the more volatile portions of gasoline will vaporize. Since only vaporized fuel will burn and because only the more volatile portions will vaporize at low temperatures, the pilot must increase the fuel-air ratio to produce a combustible mixture for starting by priming and mixture enrichening.



A S T M APPARATUS FOR DISTILLATION TEST

Fig. 11

The 10 per cent point serves as a useful index in comparing vapor locking tendencies of different fuels. In contrast to the low 10 per cent point desired for starting, a high 10 per cent point is essential to avoid vapor locking. In addition to vapor pressure and 10 per cent point, the 20 per cent point is also used to study vapor locking tendencies.

50% Point—The warming up and throttle response characteristics may be judged from the 50 per cent point. Obviously, a short warmup period is desirable, although the time required to heat the lubricating oil usually exceeds the time required to heat up the intake system.

Throttle response is important, however, particularly to assure maximum power for takeoff or in cases of overshooting the field. When the throttle is suddenly opened, the equilibrium of vaporized and liquid fuel in the inlet system is affected, and may upset the fuel-air mixture sufficiently to momentarily interrupt engine operation. In this respect an aviation gasoline of the type

plotted should be much better than the motor fuel shown for comparison.

90% *Point*—With present specifications of aviation gasoline, the 90 per cent point is relatively unimportant. In motor fuels the 90 per cent point is a factor in comparing relative gasoline dilution tendencies.

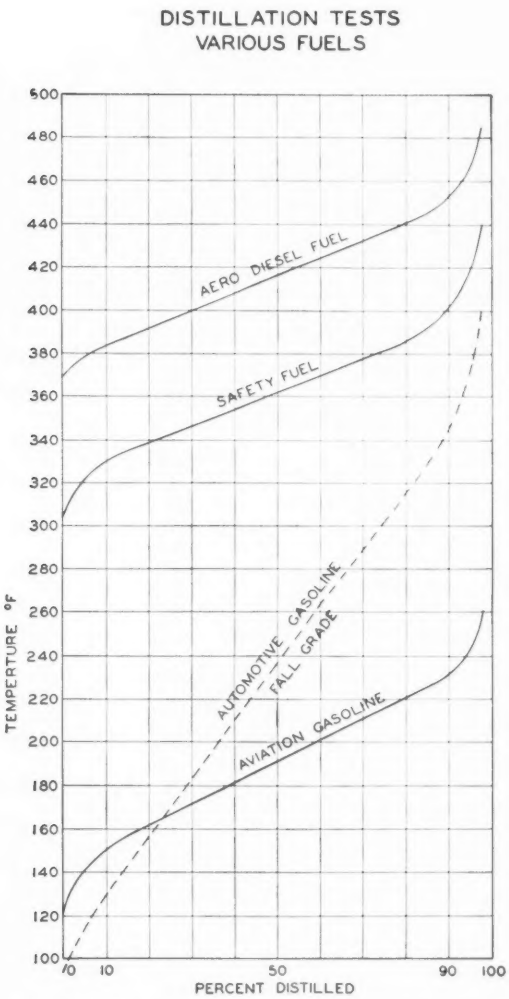


Fig. 12.—Curves showing distillation properties of aviation gasoline, automotive gasoline, aviation safety fuel and Aero Diesel fuel.

Vapor Pressures

The Reid Method of determining vapor pressure is the standard ASTM method. The procedure followed in this test is described in the following:— First, both gasoline and fuel chamber of the Reid bomb are chilled separately to a temperature between 32 degrees Fahr. and 40 degrees Fahr. Second, after filling the fuel chamber with gasoline, the former is attached to the air chamber. Third, the entire bomb is submerged in a water bath at a temperature of 100 degrees Fahr. for five minutes. Fourth, the bomb is removed from the bath, shaken, and submerged again for another two minutes. The pressure is noted on the Bourdon gage attached to the bomb before removal from the bath. This removal from the bath and shaking is continued until a constant reading is noted on the gage. Finally, corrections are made for the partial pressures of water vapor and air and applied to the pressure noted on the Bourdon gage.

This test is used in connection with the 10 per cent and 20 per cent points from the distillation test in vapor locking studies. As mentioned above, a high 10 per cent point is desired to avoid vapor locking. At the same time, a low vapor pressure is necessary for the same reason. Briefly, vapor locking is that condition in the fuel system where an excessively rapid formation of vapor bubbles interferes with the normal flow of fuel. While small amounts of vapor formation are often found, it should be remembered that the carburetor is intended to meter liquid fuel. Consequently, if excessive vaporization occurs, a mixture of vapor and liquid fuel is delivered to the carburetor or to the metering jets therein, which disrupts the proper mixture ratio, causing momentary or even complete power failure.

The vaporization tendency increases with increase in altitude, assuming there is little change in temperature. Therefore, a low vapor pressure is very important in gasoline used at high altitudes to avoid difficulties from vapor locking.

Copper Dish Gum

Although not adopted by the ASTM, the copper dish gum test is commonly used. This method requires the evaporation of 100 ml. of gasoline from a polished copper dish at a controlled rate. The remaining residue is expressed in milligrams per 100 ml. of sample. This method is often referred to as the copper dish residue test.

This test gives an indication of the resinous compounds which may form in gasoline either in storage or in prolonged contact with copper. The gum formed may become insoluble upon evaporation. Since gum deposition in the fuel system or carburetor is a definite hazard, all aviation gasoline specifications include a rigid gum specification.

Accelerated Gum Test

Two hundred ml. of gasoline are placed in a bomb with a strip of steel and oxygen is added at 100 lb./sq. in. pressure. The bomb

is next submerged in a water bath having a temperature of 212 degrees Fahr. for five hours. The purpose of the steel strip is to catalyze or increase the rate of reaction between the fuel and oxygen. One hundred ml. of the oxidized

Courtesy of Transcontinental and Western Air, Inc.

Fig. 13—New TWA Stratoliner. Four 1100 H.P. Wright Cyclone engines on each of these ships use 90 ASTM octane no. fuel.

sample of gasoline are finally removed and evaporated in a glass dish. The amount of residue left is regarded as the "accelerated gum content" and is expressed in terms of milligrams per 100 ml.

This test provides a better means of determining the possible or potential gum which may be formed over a long period of storage. While not adopted by the ASTM, this test is, nevertheless, included in practically all aviation gasoline specifications.

Gravity

Gravity ceases to be included in practically all of the latest aviation gasoline specifications. It is a measure of the weight of a given volume of fuel, but, aside from this fact, its only other significance at present is purely historical.

SAFETY OR HIGH FLASH FUELS

Safety or high flash fuels are generally regarded as those fuels with a boiling point range above 300 degrees Fahr., and a flash point of 105 degrees Fahr. minimum (Fig. 12). Hydrocarbon fractions with a boiling range between 300 and 400 degrees Fahr. are certainly not new and have been used as cleaners naphtha for years. The octane number until recently has been approximately 40, making it worthless as an aviation fuel. However, with the advent of new refining processes it has been possible to raise octane ratings upwards to 100. Present safety fuels have flash points of 105 degrees Fahr. minimum. This means that a lighted match would be extinguished if dropped into this fuel in an open dish at temperature below 105 degrees Fahr. Aviation gasoline on the other hand will instantly catch fire upon contact with a flame at temperatures down to approximately −30 degrees Fahr.

The alkylation process not only is very useful in making aviation gasoline, but is also a good method of making safety fuels. When made by the alkylation process, safety fuels compare favorably with the best aviation gasoline in octane number, stability in storage, lead sensitivity and heat value.

The use of safety fuels in modern aircraft engines, however, requires a few design changes. In starting a cold motor it is necessary to prime it with a more volatile fuel such as gasoline. In place of the carburetor an injection system is desirable. These fuels can be used with a carburetor much as tractor fuels are used with a carburetor. However, the intake air would require preheating which is undesirable in aircraft engines in view of loss in power and increased tendency towards detonation. Fuel distribution by such a method would probably be very poor.

By replacing the carburetor with an injection system good atomization and mixing can be obtained plus excellent distribution without

the necessity of preheating the air. Injection of this fuel directly into the cylinder through a nozzle in the cylinder head is probably the best method tried to date. Except for the injection apparatus no other basic changes are required. The ignition system remains the same as on the carburetor engine.

Comparative engine performance using safety fuel and gasoline of equal octane number, both used in an injection engine, show practically identical horsepower, B.M.E.P. and fuel consumption. Comparing an injection engine using safety fuel with a carburetor engine using gasoline is quite different however. In the former we have better volumetric efficiency and an increase in power, freedom from carburetor icing, better distribution and about the same fuel economy.

Safety fuels promise to eliminate vapor lock

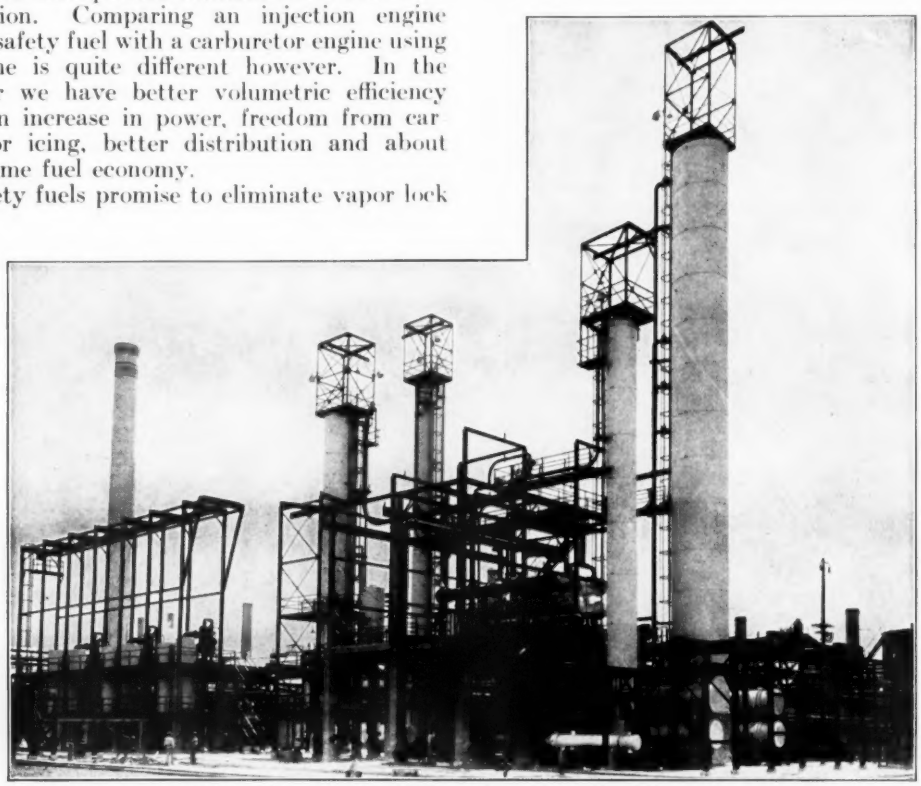


Fig. 14—Port Arthur Alkylation Plant of The Texas Company.

encountered with gasoline at very high altitudes. The reason is obviously due to a negligible vapor pressure at 100 degrees Fahr. As explained under the gasoline discussion, vapor locking is that condition in the fuel system where an excessively rapid formation of vapor bubbles interferes with the normal fuel flow.

Conversion of aircraft engines to handle safety fuel is still in the experimental stage. One manufacturer however, deserves credit for already offering an engine with fuel injection in place of the carburetor. Just exactly when and to what extent safety fuels will be used is still a moot question and rests in the hands of the operators and engine companies. The potential supply of safety fuel appears to be adequate to meet the anticipated demand.

DIESEL FUELS

The Diesel engine for aircraft offers greater possibilities in reducing fire hazard than even with engines using safety fuel. While the development of the aircraft Diesel engine has not been as active as the spark ignition engine, it is anticipated that this development work may become more active in the future. In truck, bus, marine and tractor service, Diesel engine development has been extremely active and great strides have been made within the past few years. It is expected that many of the lessons learned regarding the combustion in the automotive Diesel can be used advantageously in aircraft Diesel development. Because of the higher maximum pressures in the Diesel engine, this type of motor has been slightly heavier than the spark ignition engine of similar horsepower. Lower fuel consumption, freedom from carburetor icing, no radio interference, are among the advantages claimed for the Diesel engine in aircraft service. In addition, this engine lends itself readily to operation on the 2 cycle principle. These engines also respond well to power increase from supercharging. It might be added here that special fuels are not required as in the case

of the spark ignition engine where supercharging is employed.

The physical properties of importance in an aviation Diesel fuel are:—ignition quality, distillation range, pour point, carbon residue, sulfur content and water and sediment. Viscosity at one time was also considered important but has given way to pour point and distillation range requirements. It was believed for some time that the viscosity of a Diesel fuel had to be above a certain value for proper injection pump lubrication until it was discovered that these pumps would handle gasoline very well.

Ignition quality is important in the aircraft Diesel fuel. This is a measure of its ability to spontaneously ignite at the proper time in the cylinder or combustion chamber. Good ignition properties permit easy starting at low temperatures, reduce knocking and decrease engine roughness. Knocking in a Diesel engine is quite different from knocking in a gasoline or spark ignition engine. The Diesel knock is due to the sudden or spontaneous ignition of a quantity of fuel that accumulated in the combustion chamber during the ignition delay period. The latter is that interval between the start of fuel injection and the start of combustion. A fuel having a good ignition quality will ignite shortly after injection preventing an excessive accumulation of fuel before the start of combustion.

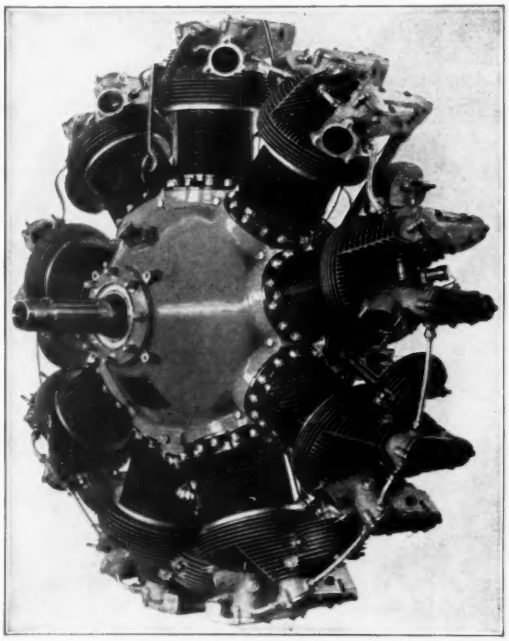
Measurement of ignition quality in Diesel fuels is based upon cetane rating or Diesel Index.

Contrary to the popular belief, the modern high speed Diesel will not function properly on crude oil. Depending upon the particular engine, definite distillation specifications are desirable. Too many heavy ends contribute to a smoky exhaust, poor combustion and piston ring gumming. The distillation range given in Fig. 12 shows a very satisfactory type of aviation Diesel fuel.

CONCLUSION

The remarkable strides in boosting engine power output is indeed a tribute to the engine manufacturers. Likewise the development of high octane fuels on a commercial scale is equally impressive. It is estimated that over half of the resultant horsepower increase has been possible due to higher octane ratings. The economic value of these fuels is already established and present transport airplanes reflect the results in greater payload or increased cruising radius.

Alkylation, hydrogenation, catalytic cracking and other processes are greatly increasing the supply of 100 octane gasoline. As a result, reliable sources have estimated that the quantity of 100 octane fuel potentially available in the United States is greater than the present production of all grades of aviation gasoline. A large increase in supply will obviously lower the cost of the 100 octane grade. Its use in transport planes is therefore anticipated provided that the engines are altered to take advantage of the higher octane rating.



Courtesy of Guiberson Diesel Engine Co.

Fig. 15—Three-quarter front view of 9 cylinder radial air cooled Guiberson Diesel engine. This engine develops 310 H.P. at 2150 R.P.M. and uses Aero Diesel fuel shown in Fig. 12.

This future trend may be altered by specifications however. Depending upon their restrictive nature, specifications can affect the supply of high octane fuels. They should be a guide to quality but at the same time must not be so inflexible or limited to serve as a barrier to the use of newer hydrocarbons. It is encouraging to note the progress made on simplification of specifications during the past few years. In 1938 fourteen different grades of aviation gasoline were required for both commercial and military services. In 1939 this was simplified to five grades for commercial and two additional ones for the military service. Next year it is anticipated that further simplification will be made so that commercial and military grades will be interchangeable.

COMMERCIAL AVIATION GASOLINE SPECIFICATIONS USED BY DOMESTIC AIRLINES.

Name	ASTM-73	ASTM-80	ASTM-87	ASTM-90	ASTM-95
Octane No., ASTM Motor Method min.	73	80	87	90	95
Tetraethyl lead, ml/gal., max.	None	2.0	3.0	4.0	4.0
Tetraethyl lead, ml/gal., min.	—	—	—	3.5	3.5
Color, Saybolt	+28	blue	blue	blue	blue
Doctor	negative	negative	negative	negative	negative
Corrosion, Copper Strip at 212 °F.	no	no	no	no	no
Corrosion, Copper Dish	no	no	no	no	no
Gum, Copper Dish mg. 100 ml., max.	5	5	5	5	5
Gum, Accelerated mg./100 ml., max.	6	6	6	6	6
Sulfur, %, max.	0.05	0.05	0.05	0.05	0.05
Distillation, Temp. °F. of					
10% Evap. Max.	158	158	158	158	158
50% Evap. Max.	212	212	212	212	212
90% Evap. Max.	257	257	257	257	257
E. P. shall not be higher than	311	311	311	311	311
Recovery, %, Min.	97	97	97	97	97
Residue, %, Max.	1.5	1.5	1.5	1.5	1.5
Loss, %, Max.	1.5	1.5	1.5	1.5	1.5
Sum of 10% and 50% Min.	307	307	307	307	307
Reid Vapor Pressure at 100 °F. lb. max.	7.0	7.0	7.0	7.0	7.0
Acidity of Residue after Distillation	neutral	neutral	neutral	neutral	neutral

Fig. 16—Aerial view of The Texas Company's Port Arthur, Texas Refinery.

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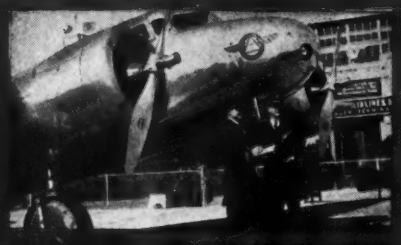
Texaco Lubrication Recommendations
for
Aircraft Engines and Auxiliaries

★ ★ ★ ★ ★

WRIGHT CYCLONE—*Series G* . .	New TEXACO Airplane Oil 120-F
OTHER ENGINES *(over 100 h.p.)* .	New TEXACO Airplane Oil 80, 100, 120, or 140 (according to manufacturers' recommendations and operating conditions).
OTHER ENGINES *(below 100 h.p.)* .	Insulated HAVOLINE or TEXACO Motor Oil SAE-20, 30, or 40 (according to manufacturers' recommendations and operating conditions).
ROCKER BOXES—*grease lubricated*	TEXACO Marfak No. 2 or No. 3
MAGNETO STARTER and GENERATOR BEARINGS	
Oil Lubricated	Insulated HAVOLINE or TEXACO Motor Oil SAE-20
Grease Lubricated	TEXACO Starfak Grease No. 2
WHEEL BEARINGS	TEXACO Starfak Grease No. 2 or No. 3 TEXACO Marfak No. 2 or No. 3
LANDING GEAR FITTINGS . . .	TEXACO Marfak No. 0, 1, or 2
CONTROLLABLE PITCH PROPELLERS	
Grease Lubricated	TEXACO Propeller Lubricant No. 00
ELECTRIC PROPELLERS	
Speed Reducer	TEXACO Spica Oil
Hub Mechanism	TEXACO Propeller Lubricant No. 00



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